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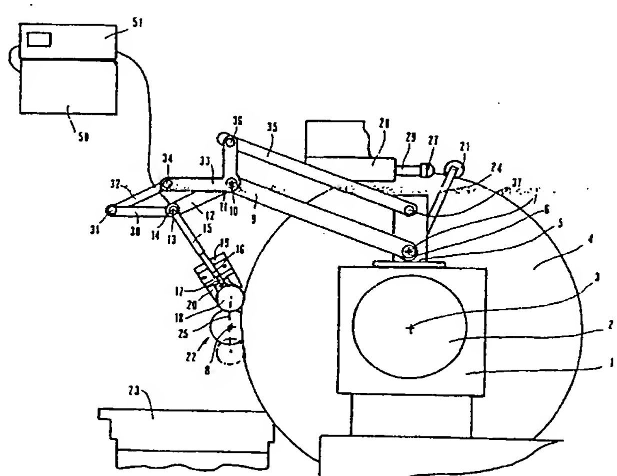

(57) **Abstract:** An apparatus for checking the diameter and the roundness of pins, for example crankpins and main journals of a crankshaft rotating about its main axis of rotation (8), includes a measuring device, coupled to a Vee-shaped reference device (20) and including a feeler (17) axially movable along the bisecting line of the Vee, or a direction slightly sloping with respect to it, and a movable support device for the reference Vee.The support device includes a support element (5) and a coupling mechanism that carries the reference Vee (20). The coupling mechanism includes, for example, two support sections (e.g. parallelogram structures) in series and enables plain translation displacements of the reference Vee. While checking an orbitally rotating crankpin, the Vee-shaped device maintains proper contact with the surface of the pin by virtue of the force of gravity, and the angular arrangement of the direction along which the feeler (17) moves remains substantially unchanged.

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«APPARATUS FOR CHECKING DIMENSIONAL AND GEOMETRICAL FEATURES OF PINS»

Technical Field

The present invention relates to an apparatus for checking dimensional and geometrical features of a pin, rotating about a geometrical axis of rotation, with a Vee-shaped device that defines rest and reference surfaces adapted for cooperating with the pin to be checked, a measuring device, coupled to the Vee-shaped device and including a feeler for contacting the surface of the pin to be checked and performing linear displacements along a measurement direction laying between the rest and reference surfaces of the Vee-shaped reference device, and a support device for supporting the Vee-shaped device and the measuring device, the support device including a stationary support element, and a coupling mechanism with coupling elements coupled in a movable way to the stationary support element and carrying the Vee-shaped device.

Background Art

Apparatuses with these characteristics, for example for the checking of a crankpin diameter of a crankshaft rotating with orbital motion about a geometrical axis in the course of the machining in a grinding machine, are disclosed in international patent application published with No. WO-A-9712724, filed by the same applicant of the present application.

In particular, according to the embodiments shown and described in the above mentioned international patent application, the apparatuses have Vee-shaped reference devices that rest on the crankpin to be checked, and maintain correct cooperation with the surface of the

crankpin substantially owing to the force of gravity.
The embodiments disclosed in the above-mentioned patent application guarantee excellent metrological results and small forces of inertia, and the standards of performance of the apparatuses with these characteristics, manufactured by the applicant of the present patent application, confirm the remarkable quality and reliability of the applications. Furthermore, these known apparatuses can be utilized for carrying out roundness checkings of the cylindrical surfaces of the pins, while the crankshaft is assembled and rotates on the grinding machine.
International patent application published with No. WO-A-0166306, filed by the same applicant of the present patent application, relates to an apparatus and a method for checking the roundness of crankpins in orbital rotation on a grinding machine. This international patent application describes the detecting of diameter dimensions of the crankpin, at predetermined angular positions of the crankshaft rotation, by means of a gauging head including a feeler and Vee-shaped reference surfaces that rest on the piece and a transducer that detects displacements of the feeler along a direction of measurement coincident with the bisecting line of the Vee or slightly inclined with respect to it.
The detected dimensions are processed, for both compensating alterations due to the particular type of head used (modulation of the shape errors of the checked surface that is in contact with the reference Vee) and carrying out other compensations for keeping into account the position taken by the head on the surface of the crankpin, more specifically the angularly arranged position of the point of contact of the feeler with respect to a known reference position, that depends on the relative arrangement between the support element and the crankshaft and on the characteristics and consequent configurations taken by the support device carrying the head. Figures 1a and 1b show, in an extremely simplified form, some parts of a known

apparatus, coupled to the grinding-wheel slide of a grinding machine, in the course of the checkings of a cylindrical crankpin. In order to emphasize how the angular arrangement of the measurement direction **D** defined by feeler **T** depends on the mutual position between piece to be checked and coupling area of the apparatus, figures 1a and 1b show two different checking conditions. In the first condition (figure 1a) the apparatus checks the pin while the latter is in contact with the grinding wheel, in the second condition (figure 1b), the checking takes place while the grinding-wheel slide is retracted with respect to the piece. It is also necessary to realize that in the course of the checking of a pin in orbital motion (for example a crankpin), variations in the configuration of the support device cause consequent variations in the angular arrangement of the feeler.

The method according to international patent application WO-A-0166306 enables to achieve excellent results, notwithstanding the unavoidable approximations due to the various processings, that are based on the theoretic behavior of the involved mechanic parts.

Disclosure of Invention

Object of the present invention is to provide an apparatus for the dimensional and geometrical checking of pins rotating in the course of the machining in a machine tool, for example for the in-process checking, in a grinding machine, of crankpins rotating with an orbital motion, that guarantee the same standards of performance, in terms of accuracy and reliability, as those of the apparatuses according to the above-mentioned international patent applications and enables a simpler checking of the roundness characteristics of the pins.

This problem is solved by a checking apparatus of the hereinbefore mentioned type, wherein the coupling mechanism further includes constraining elements adapted for enabling

substantially translation displacements of the Vee-shaped device with respect to the stationary support element.

The support element according to the invention enables the Vee-shaped reference device and the measuring device to accomplish substantially plain translation displacements in the plane perpendicular to the axis of rotation. In other words, as shown in simplified form in figures 2a and 2b, the angular arrangement of the measurement direction **D** along which feeler **T** translates does not vary when the arrangement of the various parts forming the support device vary.

An advantage that the present invention provides is that of setting beforehand and regardless of the mutual position between support element and piece to be checked the angular arrangement of the contact direction of the feeler on the surface of the piece to be checked. In this way, should there be the need, for example, to utilize the apparatus for roundness checkings, at least part of the processings of the detected values - required for the checkings carried out by the known apparatuses - are not necessary, and this enables, among other things, to minimize the approximations in the calculations and make the checking operations more immediate and reliable.

Brief Description of the Drawings

A preferred embodiment of the invention is now described in more detail with reference to the enclosed sheets of drawings, given by way of non-limiting example, wherein:

figures 1a and 1b show, in simplified form, the arrangement of a known apparatus under two different operating conditions;

figures 2a and 2b show, in simplified form, the arrangement of an apparatus according to the invention under the two different operating conditions shown in figures 1a and 1b;

figure 3 is a side view of a measuring apparatus according to a preferred embodiment of the invention, mounted on the grinding-wheel slide of a crankshaft grinding machine, shown in working conditions in the course of the checking of a crankpin while it is being machined;

figure 4 is a partly cross-sectional view of the measuring system of the apparatus according to a first embodiment;

figure 5 is a partly cross-sectional view of the measuring system of the apparatus according to a different embodiment;

figure 6 is a side view of a measuring apparatus according to a different embodiment of the invention, mounted on the grinding-wheel slide of a crankshaft grinding machine, shown in working conditions in the course of the checking of a crankpin while it is being machined;

figure 7 is a side view of the measuring apparatus of figure 6, shown in a rest condition;

figure 8 is a side view of a measuring apparatus, mounted on the grinding-wheel slide of a crankshaft grinding machine, according to a third embodiment of the invention;

figure 9, is a partly cross sectioned side view of a measuring apparatus according to a fourth embodiment of the invention, mounted on the grinding-wheel slide of a crankshaft grinding machine; and

figure 10 is a cross-sectional view of a particular of the apparatus of figure 9, along the line X-X of figure 9.

Best Mode for Carrying Out the Invention

With reference to figure 3, the grinding-wheel slide **1** of a computer numerical control ("CNC") grinding machine for grinding a crankshaft supports a spindle **2** that defines the axis of rotation **3** of the grinding wheel **4**. The grinding-wheel slide **1** carries a support device with a stationary support element **5** and a coupling mechanism including

coupling and constraining elements. More specifically, the support element **5** supports, by means of a rotation pin **6**, a first rotating coupling element **9**. Pin **6** defines a first axis of rotation **7** parallel to the axis of rotation **3** of grinding wheel **4** and to the axis of rotation **8** of the crankshaft to be checked. In turn, coupling element **9**, by means of a second rotation pin **10**, defining a second axis of rotation **11** parallel to axes **3** and **8**, supports a second rotating coupling element **12**. At the free end of the second coupling element **12** there is coupled, by means of a third rotation pin **13** defining a third axis of rotation **14** parallel to axes **3** and **8**, a guide casing **15** wherein there can axially translate a transmission rod **16** carrying a feeler **17** for contacting the surface of crankpin **18** to be checked. The displacements of rod **16** are detected by a measuring device, as hereinafter disclosed. At the lower end of the guide casing **15** there is coupled a support block **19** that supports a Vee-shaped reference device **20**, with rest and reference surfaces for engaging the surface of crankpin **18** to be checked. Feeler **17** and transmission rod **16** are movable substantially along a measurement direction that coincides with the bisecting line of the Vee-shaped reference device **20**, or is slightly angular with respect to it, but in any case crosses the Vee-shaped device **20** between the associated rest and reference surfaces.

The guide casing **15** is rigidly coupled (angularly adjustable in a known way that is not shown in detail in the figures) to a connecting rigid strip **30**, also hinged on the rotation pin **13**, and coupled, by means of a further pin **31**, to an elongate element or rod **32**. A linking element in the shape of an "L" or square **33** is hinged on pin **10**, and, at a first end, by means of a pin **34**, to rod **32**. Another elongate element or rod **35** is hinged on the other end of the square **33** (by means of a pin **36**) and on support element **5** (by means of a pin **37**).

A crankshaft **22** to be checked is positioned on the worktable **23**, between centers, not shown, that define the

axis of rotation **8**, coincident with the main geometrical axis of crankshaft **22**. Consequently, crankpin **18** performs an orbital motion about axis **8**. Even though crankpin **18** eccentrically rotates about axis **8**, by describing a circular trajectory, the trajectory of the pin relative to the grinding-wheel slide **1** in the course of the machining can be represented, substantially, by the arc shown with a dashed line and identified by reference **25**. As a consequence, the reference device **20**, resting on crankpin **18**, describes a similar trajectory, with a reciprocating motion from up to down and vice versa and at a frequency equal to that of the orbital motion of crankpin **18** (some tens of revolutions per minute). This is due to the fact that the checking apparatus is carried by the grinding-wheel slide **1** that, in modern numerical control grinding machines, machines the crankpins while they rotate in an orbital motion, by "tracking" the pins so as to keep the grinding-wheel in contact with the surface to be ground. Obviously, a feed motion for the stock removal is added to the transversal "tracking" motion. Thus, it is understood that the displacements of the elements forming the checking apparatus involve relatively small forces of inertia, to the advantage of the metrological performance, limited wear and reliability of the apparatus.

A control device, schematically shown in figure 3, includes a double-acting cylinder **28**, for example of the hydraulic type. Cylinder **28** is supported by grinding-wheel slide **1** (in a known way, not shown in the figure) and comprises a rod **29**, coupled to the piston of cylinder **28**, carrying a cap **27** at its free end. A transmission arm **24** is rigidly and angularly coupled to the coupling element **9** and carries a positive stop element with an idle wheel **21**. When cylinder **28** is activated for displacing the piston and the rod **29** to the right (with reference to figure 3), cap **27** contacts idle wheel **21** and makes the apparatus displace to a rest position according to which reference device **20** is

arranged above the geometric axis **8** and the upper position of crankpin **18**.

The retraction of the checking apparatus to the rest position is normally controlled by the grinding machine numerical control when, on the ground of the measuring signal of the checking apparatus, it is detected that crankpin **18** has reached the required (diametral) dimension. Thereafter, the machining of other parts of the crankshaft takes place, or - in the event the machining of the crankshaft has been completed - the piece is unloaded, manually or automatically, and a new piece is loaded on worktable **23**.

When a new crankpin has to be machined, it is brought in front of grinding wheel **4**, usually by displacing worktable **23** (in the case of a grinding machine with a single grinding wheel), and the apparatus displaces to the checking condition. This occurs by controlling, by means of the grinding machine numerical control, cylinder **28** so that rod **29** is retracted.

Thus, cap **27** disengages from idle wheel **21** and, through rotations of the coupling elements **9**, **12** and the guide casing **15**, due to the specific weight of the component parts of the checking apparatus, reference device **20** approaches, by performing a trajectory with a mainly vertical component, crankpin **18**, that in the meanwhile moves according to its orbital trajectory **25**. Once the correct cooperation between crankpin **18** and reference device **20** is reached, this cooperation is maintained in the course of the checking phase by virtue of the displacements of the coupling elements **9**, **12** and the guide casing **15** caused by the force of gravity and by the thrust of crankpin **18**, the latter opposing the force of gravity of the component parts of the checking apparatus.

It should be realized that the mechanism for coupling the measuring device to the support element **5** that includes, in addition to the first **9** and second **12** coupling elements, constraining elements including corresponding rods **35** and

32, the linking element **33** and the connecting strip **30**, defines two parallelogram structures. These parallelogram structures that, as previously described, define axes of rotation parallel to the axes of rotation **3** and **8** of grinding wheel **4** and of crankshaft **22** to be checked, enable substantially plain translation displacements of the guide casing **15** and of the reference device **20** fixed to it, in other words enable to keep the angular arrangement of the direction of measurement along which feeler **17** displaces unchanged, regardless of the configuration taken by the various component parts of the coupling mechanism.

This facilitates, among other things, the checking of the roundness characteristics of the orbiting pin, because, as the angular arrangement of the contact direction of the feeler on the surface of the pin is known and constant (as shown in the sketches of figures 2a and 2b), the values detected by means of the measuring device need not undergo the associated compensations mentioned in the first part of the present description. In substance, the detected values do not depend on the reciprocal position between support element **5** and checked crankshaft **22** and on the characteristics and consequent configurations taken on by the support device carrying the measuring device.

Figure 4 shows some details of a possible embodiment of a device, or measuring head, **39** utilized in the apparatus according to the invention. The axial displacements of transmission rod **16** with respect to a reference position are detected by means of a measurement transducer fixed to casing **15**, for example a transducer **41** of the LVDT or HBT known type with fixed windings **44** and a ferromagnetic core **43** coupled to a shaft **42** integral with transmission rod **16**. The axial displacement of the transmission rod **16** is guided by two bushings **45**, arranged between casing **15** and rod **16** and a compression spring **49** urges rod **16** and feeler **17** towards the surface of pin **18** to be checked or, in the absence of the pin, towards a rest position of feeler **17** defined by abutment surfaces not shown in the figures. A

metal bellows **46**, that is stiff with respect to torsional forces and has its ends fixed to rod **16** and to casing **15** or a portion of block **19** integral to it, respectively, accomplishes the dual function of preventing rod **16** from rotating with respect to casing **15** (thus preventing feeler **17** from taking improper positions) and sealing the lower end of casing **15**.

The support block **19** is secured to guide casing **15** by means of pairs of screws **47** passing through slots **48** and supports the reference device **20**, consisting of two elements **38** with sloping surfaces, whereto there are secured two bar shaped feelers **40**. The rest position of feeler **17** can be adjusted by means of the screws **47** and slots **48**.

The transducer **41** of measuring head **39** is connected to a processing and display device **51**, in turn connected to the grinding machine numerical control **50** (both schematically shown in figure 3).

Figure 5 shows a device, or measuring head, **39'** that differs with respect to head **39** insofar as the asimmetric arrangement of the Vee-shaped reference device **20'** is concerned, the latter being arranged in such a way that the direction of measurement along which feeler **17** translates is angularly sloping with respect to the bisecting line of the Vee. In the example shown in figure 5, the amplitude of angles **α1** and **α2** is 47° and 33°, respectively. The use of the asimmetric Vee **20'** is particularly advantageous for carrying out roundness checkings by means of an apparatus according to the present invention, in that it increases the apparatus sensitivity thereby enabling the checking of cylindrical surfaces with lobed cross-sections in a broad range of orders.

Figures 6 to 9 show, in a particularly simplified form, different possible embodiments of an apparatus according to the present invention.

More specifically, the apparatus according to figures 6 and 7 differs from the one shown in figure 3 in that it includes a different linking element achieved by means of a

plate **33′** on which there are hinged coupling elements **9** and **12** and rods **32** and **35**. With respect to the embodiment shown in figure 3, the second coupling element **12** is coupled to plate **33′** by means of an additional rotation pin **10′** in a stationary position with respect to pin **10**.

An additional feature is present in the embodiment of figures 6 and 7 with respect to figure 3, i.e. an adjusting device with a plate **60** coupled to pin **6**, pivotable about the first axis of rotation **7**, and carrying pin **37′** to which rod **35** is pivotably coupled.

The angular position of the adjusting plate **60** with respect to the support element **5** is fixed during the checking condition of the apparatus, thus fixing a side of one of the parallelogram structures, and consequently determining the angular arrangement of the direction of measurement along which feeler **17** displaces, as hereinbefore explained with reference to figure 3. The angular position of the adjusting plate **60** can be changed by means of known mechanical devices (not shown in the drawings) causing pivoting movements of plate **60** about axis **7**, in order to change the above-mentioned angular arrangement of the direction of measurement along which feeler **17** displaces. The adjusting plate **60** can then be fixed in the new, modified position (by means of known mechanical means, not shown in the drawings), in order to perform new checking operations. This feature increases the flexibility of use of the apparatus, allowing easy and quick adjustments to obtain better performances in applications having different features as far as dimensions and/or arrangement of machine components are concerned. Moreover the angular position of adjusting plate **60** can be changed and then fixed (e.g. by automatic means) also while moving from the checking condition to the rest position (and vice-versa), in order to guarantee a safer position of the measuring head **39**, far from the grinding wheel **4** and other moving machine parts, while the apparatus is in the inoperative condition shown in figure 7.

The adjusting plate **60** can be employed in the embodiment of figure 3, too.

In the apparatus shown in figure 8, one of the two parallelogram structures is replaced by a linear guide or slide - shown in simplified form in the figure and identified by reference number **70** - by means of which a linking element **33''** is coupled, in a slidably constrained way, to the support element **5**. The coupling element or arm **12** and rod **32** are coupled to the linking element **33''** by means of the pins **10'** and **34**, respectively. An adjusting plate similar to the one (**60**) of figure 6 and 7 can be connected to plate **33'**, pivotable about pin **10'** and carrying pin **34**.

The support devices of the embodiments shown in figures 6, 7 and 8 have coupling mechanisms that include, as the support device shown in figure 3, coupling elements and constraining elements that enable reference Vee **20** (or **20'**) to approach to and displace away from pin **18** to be checked - and to "track" pin **18** in its orbital trajectory - by performing translation displacements according to which the direction of measurement defined by the displacements of feeler **17** and of transmission rod **16** remains substantially parallel to itself.

The embodiments shown in figures 3 and 6 to 8 are illustrated as an example only, while other embodiments fall within the scope of the invention. For example, the coupling mechanism of the support device can include two support sections coupled "in series" - like the parallelogram structures of figures 3, 6 and 7, or the slide and the parallelogram structure of figure 8 - and each of the two sections defines constraints that allow just plain reciprocal translation displacements among the coupled parts. Besides the parallelogram type structures and slides, there are other known devices that have the above mentioned features, for example the coupling mechanism schematically shown in the embodiment of figures 9 and 10, where the two support sections include rotating

coupling elements **79** and **82** having parallelepipedon-shaped closed housings **74** and **75**, respectively. More specifically, the first coupling element **79** is pivotably connected to the support element **5** by means of a stationary pin **76** engaging bearings in the housing **74** (not shown in the figures) and defining a first axis of rotation **77.** A second pin **80** defining a second axis of rotation **81** cooperates with bearings in both housings **74** and **75** (figure 10, where, for the sake of simplicity, bearings are not shown), to allow mutual rotating movements between first and second coupling elements **79** and **82.** At the free end of the second coupling element **82,** there is coupled, by means of a third pin **83** and corresponding bearings in housing **75** defining a third axis of rotation **84,** the guide casing **15** of measuring head **39** (or **39'**).

Constraining elements include a first, stationary, pulley **85** that is fixed to stationary pin **76,** second and third pulleys **86** and **87** fixed to the second pin **80,** and a fourth pulley **88** fixed to the third pin **83.** The constraining elements also include first and second belts **89** and **90** (e.g. toothed belts) tightly coupled to the first (**85**) and second (**86**) pulleys and to the third (**87**) and fourth (**88**) pulleys, repectively. By virtue of the arrangement of the two support sections including housings, pulleys and belts as above specified, the angular arrangement of the direction of measurement along which feeler **17** displaces remains unchanged during movements of the coupling mechanism involving mutual rotation between elements **79** and **81.** In fact, during pivotal movements of coupling element **79** about axis **77,** the first belt **89** constrains the second pulley **86** to keep its angular arrangement about axis **81.** The third pulley **87** is fixed to pin **80** like pulley **86,** and consequently its angular arrangement about axis **81** remains unchanged, too. In the same way, the second belt **90** prevents fourth pulley **88** from rotating about axis **84.** As a result, the angular arrangement of the third pin **83** – rigidly fixed to pulley **88** and carrying guide casing **15** –

about axis **84** does not change during pivotal movements of the coupling elements **79** and **82**, thus keeping the angular arrangement of the direction of measurement along which feeler **17** displaces, and enabling plain translation displacements of the head **39**.

A possible additional feature of the embodiment of figures 9 and 10 consists in an adjusting device including an adjustable coupling between the first stationary pulley **85** and the support element **5**, that employs per se known means that are not shown in the drawings. The adjustable coupling allows to modify and fix the angular arrangement of the pulley **85** about axis **77**, in order to perform adjustments of the coupling mechanism in the same way as hereinbefore described in connection with the adjusting plate **60** of figures 6 and 7.

The embodiment of figures 9 and 10 has some advantages with respect to the other previously described embodiments as far as the tightness is concerned. In fact, the substantially closed structure and the possibility of easily seal the openings with bearings of housings **74** and **75**, prevent dust and coolant from interfering with the proper operation of the apparatus.

Embodiments according to the present invention can also include coupling mechanisms, per se known, not clearly divisible in two sections having the above described features, that comprise coupling elements and constraining elements the combined displacements of which enable to constrain the mutually coupled parts to accomplish substantially plain translation displacements.

Other possible variants with respect to what has been herein described and illustrated can also regard the structure and the arrangement of the control device and/or the use of limiting devices with abutment surfaces, for example for limiting the reciprocal rotations among the various parts of the support device in the rest position.

Furthermore, it is also possible to foresee an additional guide element coupled to reference device **20**, and/or a

balance spring, achieved, for example, as disclosed in international patent application WO-A-9712724.

An apparatus according to the invention is particularly suitable for the in-process checking of crankpins in orbital motion, but can obviously be utilized for dimensional or shape checkings of pins in orbital motion before or after the machining, as well as for checkings (before, during or after the machining) of pins rotating about their symmetry axes.

CLAIMS

1. An apparatus for checking dimensional and geometrical features of a pin (**18**), rotating about a geometrical axis of rotation (**8**), with

- a Vee-shaped device (**20;20'**) that defines rest and reference surfaces adapted for cooperating with the pin (**18**) to be checked,
- a measuring device (**39;39'**), coupled to the Vee-shaped device (**20;20'**) and including
  - a feeler (**17**) for contacting the surface of the pin to be checked and performing linear displacements along a measurement direction (**D**) laying between said rest and reference surfaces of the Vee-shaped device (**20;20'**), and
- a support device for supporting the Vee-shaped device (**20;20'**) and the measuring device (**39; 39'**), the support device including
  - a stationary support element (**5**), and
  - a coupling mechanism with coupling elements (**9,12;79,82**) coupled in a movable way to the stationary support element (**5**) and carrying the Vee-shaped device (**20**),

characterized in that said coupling mechanism further includes constraining elements (**30,32,33,35;33';33'',70;85-90**) adapted for enabling substantially translation displacements of the Vee-shaped device (**20;20'**) with respect to the stationary support element (**5**).

2. The apparatus according to claim 1, wherein said coupling elements (**9,12;79,82**) and constraining elements (**30,32,33,35;33';33'',70;85-90**) define two support sections coupled in series.

3. The apparatus according to claim 1 or claim 2, wherein at least some of said coupling elements (**9,12;79,82**) and constraining elements (**30,32,33,35;33';33'',70;85-90**) are

adapted to perform angular displacements about axes **(7,11,14;77,81,84)** parallel to said geometrical axis of rotation **(8)**.

4. The apparatus according to claim 2, wherein said coupling elements **(9,12)** and constraining elements **(30,32,33,35;33';33'',70)** define a parallelogram structure with four axes of rotation parallel to said geometrical axis of rotation **(8)**.

5. The apparatus according to claim 4, wherein said coupling elements **(9,12)** and constraining elements **(30,32,33,35;33')** define an additional parallelogram structure with four additional axes of rotation parallel to said geometrical axis of rotation **(8)**.

6. The apparatus according to claim 5, wherein each of said support sections includes one of said parallelogram structure and additional parallelogram structure.

7. The apparatus according to claim 6, wherein each of said parallelogram structure and additional parallelogram structure includes a coupling element **(9,12)** and a constraining elongate element **(35,32)**, said constraining elements further include a linking element **(33;33')** coupled in a rotating way to the free ends of said coupling elements **(9,12)** and constraining elongate elements **(35,32)**.

8. The apparatus according to claim 7, wherein said coupling elements **(9,12)** are coupled to said linking element **(33)** in a rotating way about an identical axis of rotation **(11)**.

9. The apparatus according to one of claims 2 to 4, wherein at least one of said sections includes a linear guide **(70)**.

10. The apparatus according to claim 2, wherein the constraining elements include pulleys (**85-88**) and belts (**89,90**), each of said support sections including a rotating coupling element (**79,82**), a couple of said pulleys (**85-86,87-88**) and one of said belts (**89,90**).

11. The apparatus according to claim 10, wherein each of said support sections includes a substantially closed housing (**74,75**), said couple of pulleys (**85-86,87-88**) and belt (**89,90**) being arranged within the housing (**74,75**).

12. The apparatus according to claim 11, wherein one of said support sections include a first stationary pulley (**85**) coupled to the stationary support element (**5**), a second pulley (**86**) and a first belt (**89**) coupled to said first and second pulleys (**85,86**), the other of said support sections including a third pulley (**87**), a fourth pulley (**88**) and a second belt (**90**) coupled to said third and fourth pulleys (**85,86**), the Vee-shaped reference device (**20;20'**) and the measuring device (**39;39'**) being rigidly connected to the fourth pulley (**88**), the second (**86**) and the third (**87**) pulleys being mutually rigidly connected.

13. The apparatus according to one of the preceding claims, further including an adjusting device (**60**) coupled to at least one of said constraining elements (**30,32,33,35;33';33'',70;85-90**) for adjusting and fixing the angular arrangement of said measurement direction (**D**).

14. The apparatus according to claim 5, further including an adjusting device (**60**) coupled to one of said parallelogram structure and additional parallelogram structure for adjusting and fixing the angular arrangement of said measurement direction (**D**) by adjusting the mutual position of at least two of said axes of rotation and additional axes of rotation.

15. The apparatus according to claim 14, wherein said adjusting device (**60**) is coupled to the stationary support element (**5**) and to one of said parallelogram structure and additional parallelogram structure.

16. The apparatus according to one of the preceding claims, including a control device for controlling automatic displacements of the measuring device from a rest position to a checking condition and vice versa.

17. The apparatus according to one of the preceding claims, for the diameter and the roundness checking of a pin (**18**) orbiting about a geometric axis of rotation (**3**), in the course of the machining in a numerical control grinding machine with a worktable that defines said geometric axis and a grinding-wheel slide (**1**) carrying a grinding-wheel (**4**), wherein the stationary support element (**5**) is coupled to the grinding-wheel slide.

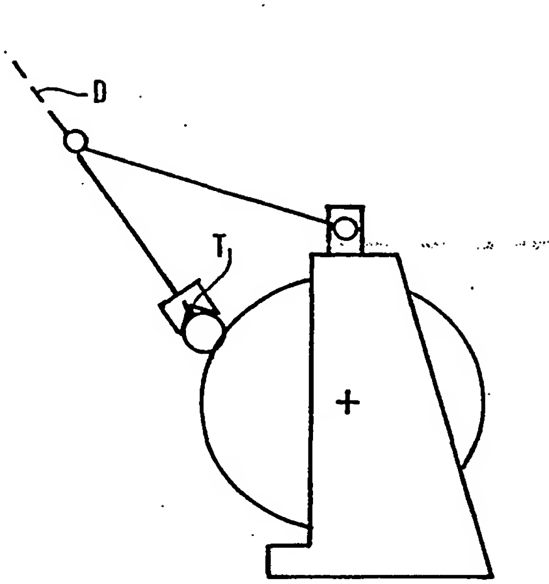

FIG. 1a

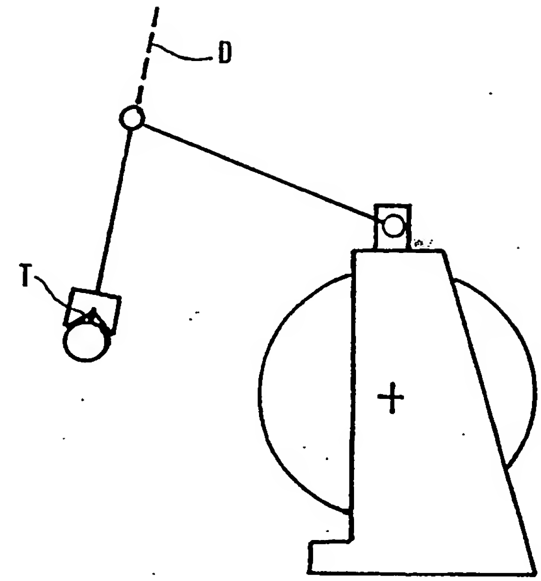

FIG. 1b

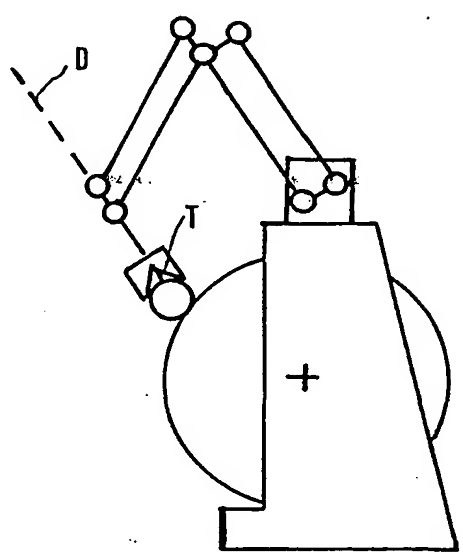

FIG. 2a

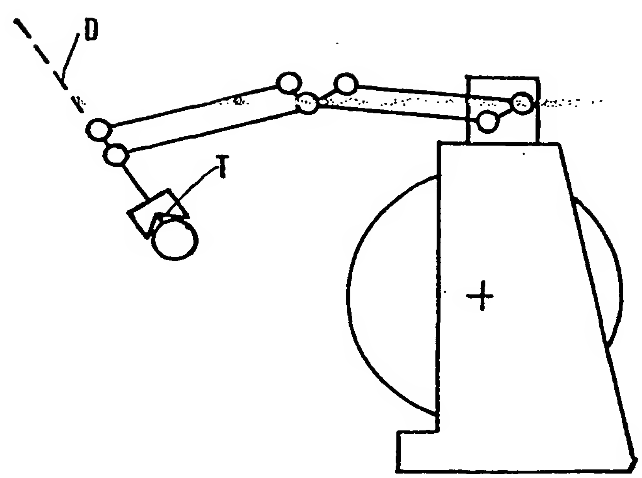

FIG. 2b

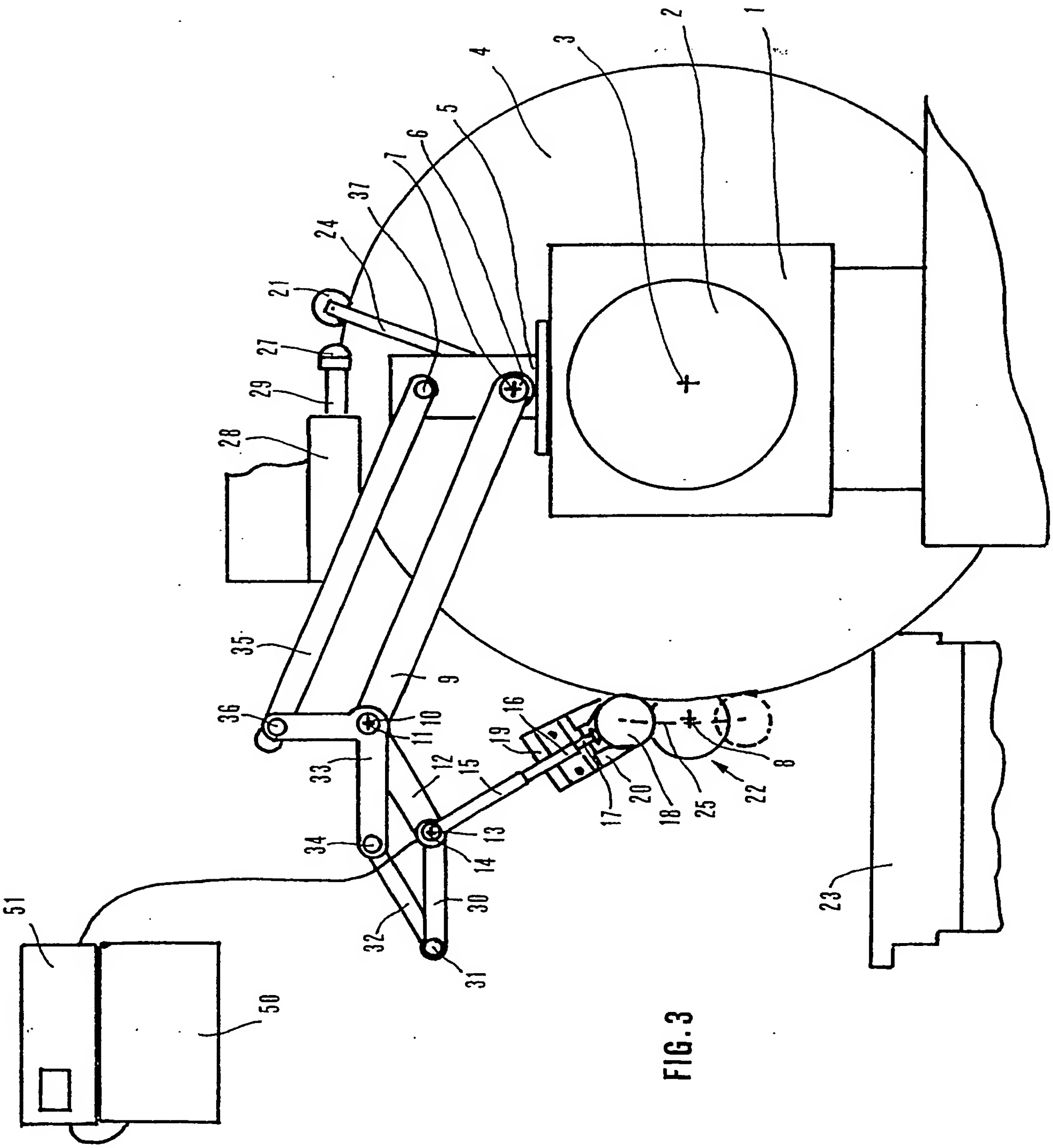
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FIG. 3

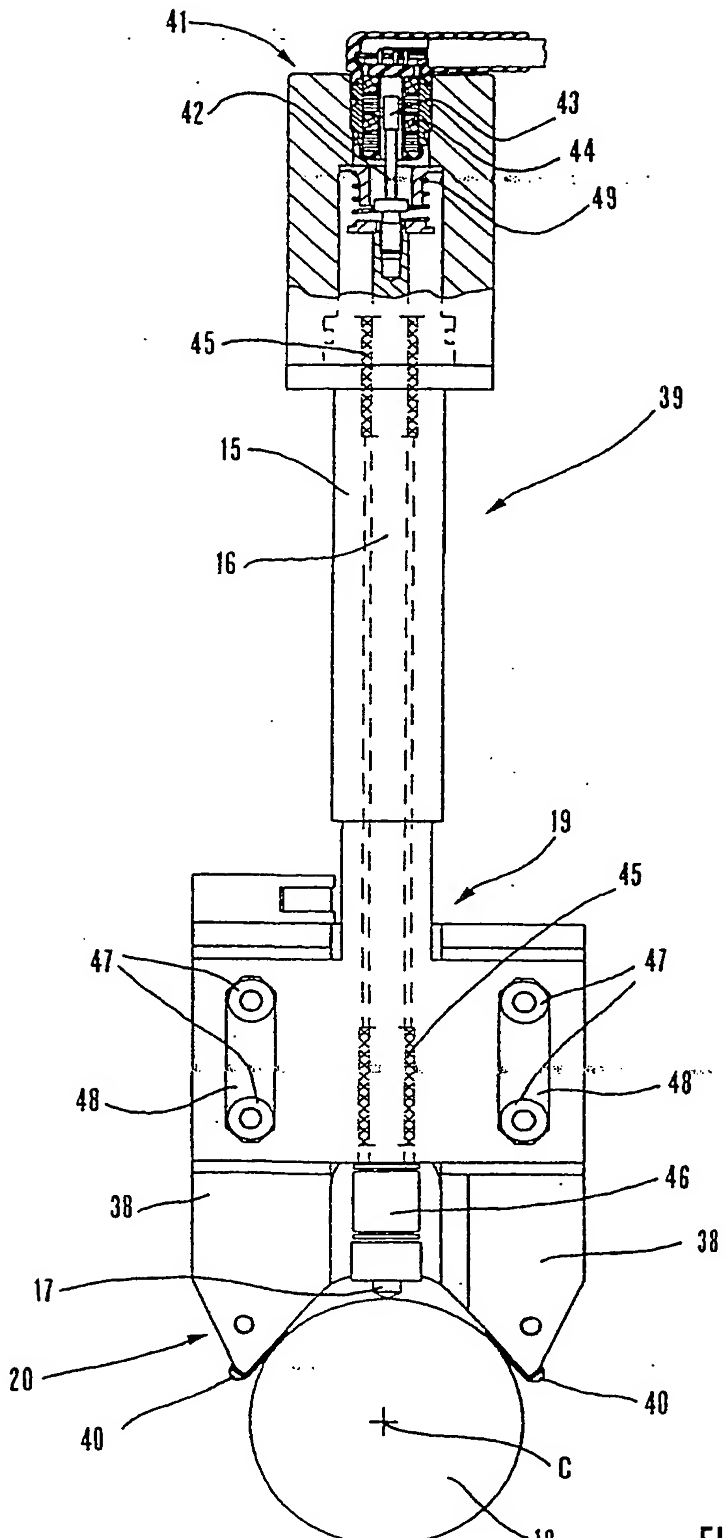


FIG.4

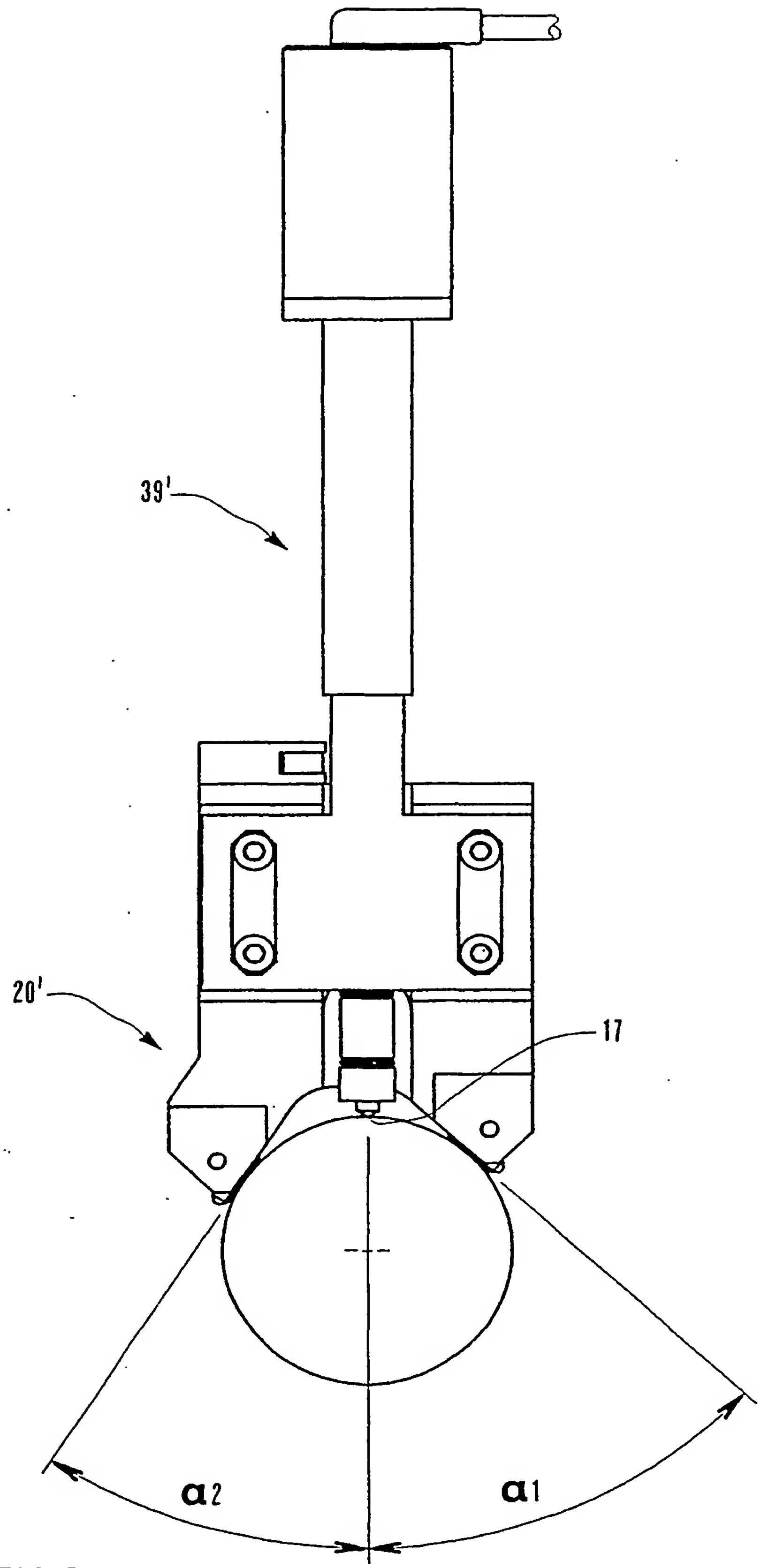
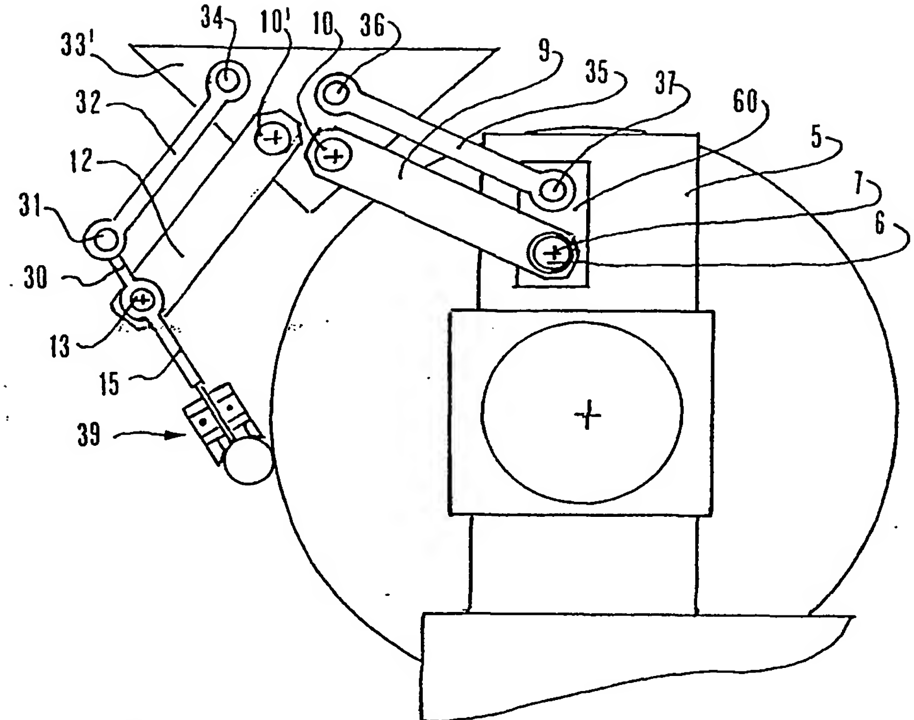


FIG.5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10'
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33'
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35
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60
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31
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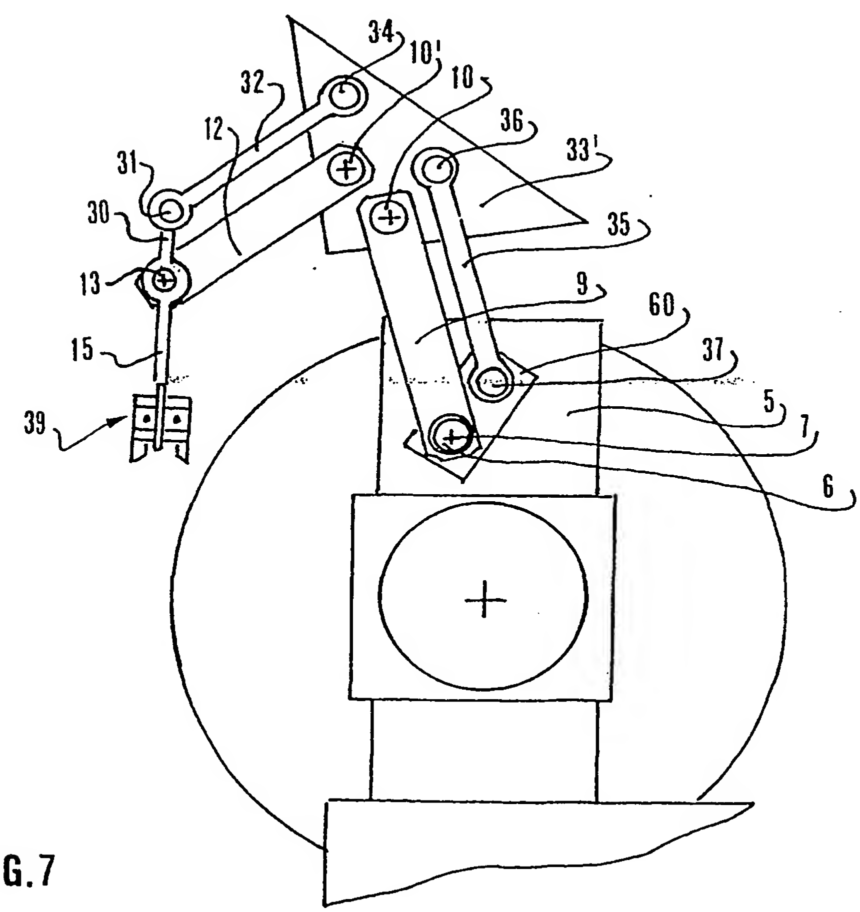
FIG. 6


34
10'
32
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36
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33'
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60
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FIG. 7

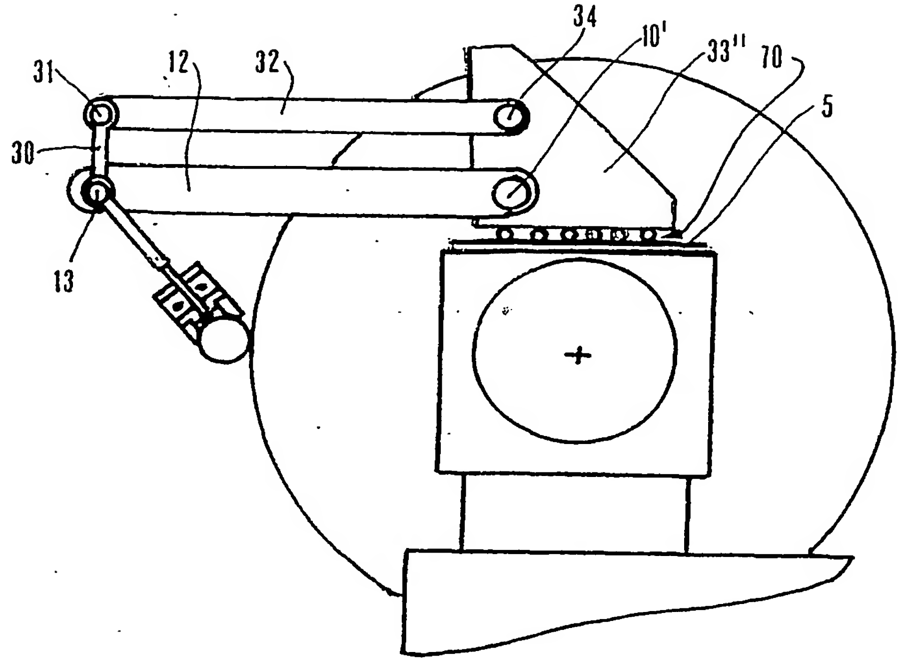
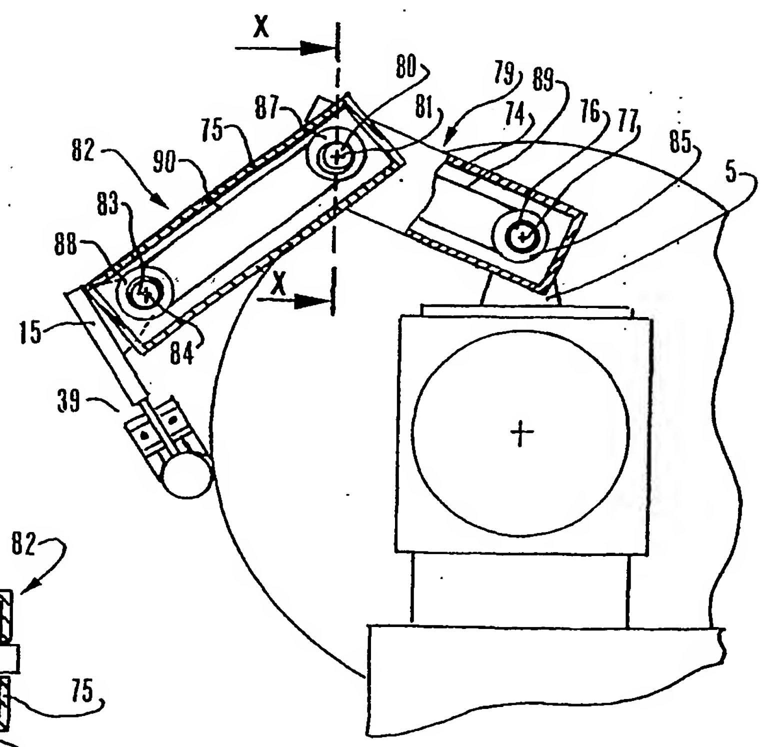


FIG. 8



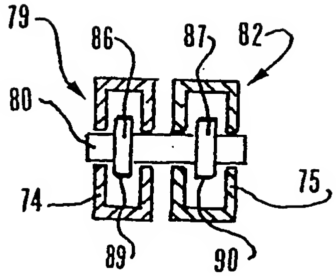


FIG. 10

FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No
EP 02/02022

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B24B5/42 B24B49/04 G01B5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B24B G01B B23Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 903 199 A (UNOVA UK LTD) 24 March 1999 (1999-03-24) paragraphs '0053!,'0057!,'0058!,'0074!,'0095!-'0112!	1-4,9, 16,17
A	figures 1,4	13
Y	WO 97 12724 A (MARPOSS APP ELETT ;DALL AGLIO CARLO (IT); CIPRIANI RICCARDO (IT)) 10 April 1997 (1997-04-10) cited in the application page 6, line 11 -page 14, line 12 figure 1	1-4,9, 16,17
A	US 6 088 924 A (ESTEVE XAVIER) 18 July 2000 (2000-07-18) column 4, line 20 - line 50 figure 4	1,3,4,9, 17

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 July 2002	09/07/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schultz, T

INTERNATIONAL SEARCH REPORT

[illegible]ation on patent family members

In[illegible]ional Application No
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